Fast Determination of Layer Parameters Using Genetic Algorithm in Multilayer Mirror

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1. Introduction

Multilayer mirrors are very important role in X-ray applications because the properties of X-ray beams can be modified by them [1]. Multilayer mirrors have a period structure consisting of alternating layers of high and low densities. Each layer of the multilayer mirror should have a highly uniform thickness with sharp surface (or interfacial) edge to approach the designed performance in X-ray. The bilayer is one pair composed of each high and low density layer. The number of bilayer for multilayer mirrors is a few tens to hundreds.

Each layer of the multilayer mirror are usually deposited by using an ion-beam or magnetron sputtering system. During deposition of the multilayer mirror, properties of each layer can be changed slightly in spite of applying the same condition. Density, thickness, and surface roughness for each layer are important parameters in design and fabrication of the multilayer mirrors. Properties of each layer should be verified for the performance of the multilayer mirror. The parameters of each layer in the multilayer mirror are usually measured by X-ray reflectivity (XRR).

The parameters of the multilayer mirror are determined by fitting the XRR measurement data. It is not easy to determine parameters for each layer because the number of layer are a few tens to hundreds. Thus, it usually assumes that each bilayer have the same parameters. The assumption gives a short time in performing fitting of the XRR data. However, the parameters of each layer are given by average values instead of values for each layer. Genetic algorithm are employed for obtaining the parameters for each layer [2]. However, the analysis of data fitting using the genetic algorithm takes long time. In addition to, the use of the genetic algorithm always does not give the optimal parameters. In this paper, we improve the genetic algorithm for obtaining optimal parameters for XRR data of a W/C multilayer mirror, which shows a good performance in hard X-ray, and the calculation time by using parallel computing of GPU in a graphics card. The XRR analysis program was written in C language run on GPU.

2. Application of genetic algorithm

The genetic algorithm is one of the optimization algorithms to find an optimum solution. Three parameters, density, thickness, and surface roughness, for each layer were set to real numbers for selection in genetic algorithm. In a conventional method, only uniform real numbers were used, however the real numbers were selected by both uniform and Gaussian random numbers. The Gaussian random numbers gave fast convergence. The half of selection was given by the uniform random numbers to avoid local minima. The upper limit of the density was set to bulk density of W or C. The average thickness was set to the designed thickness of layer, and the average value of surface roughness was 0.3 nm. The fitness function was the sum of the square of the logarithmic difference between the measured XRR data and the theoretical reflectivity for the W/C multilayer mirror with selected parameters.

3. Results and Conclusion

The iteration was terminated after 100 generations. The fitting curve was shown in Fig. 1. The difference between the measured XRR data and the fitting curve obtained optimal parameters was very small. The optimal parameters was obtained with 15 seconds which was approximately 2 times improvement.

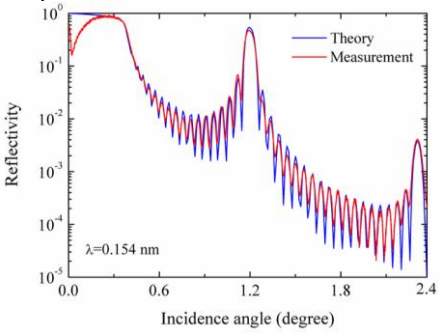

Fig.1 XRR measured data and a fitted reflectivity with optimal parameters for a W/C multilayer mirror

References

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